AU 332/342 Artificial Intelligence: Principles and Techniques
Assignment 4
Due: NOV 29th 11 : 59pm

Adhere to the Code of Academic Integrity. You may discuss background issues and general strategies with others and seek help from course staff, but the implementations that you submit must be your own. In particular, you may discuss general ideas with others but you may not work out the detailed solutions with others. It is never OK for you to see or hear another student's code and it is never OK to copy code from published/Internet sources. If you feel that you cannot complete the assignment on you own, seek help from the course staff. The homework should be finished in a group of **one**.

When submitting your assignment, follow the instructions summarized in Section 3 of this document.

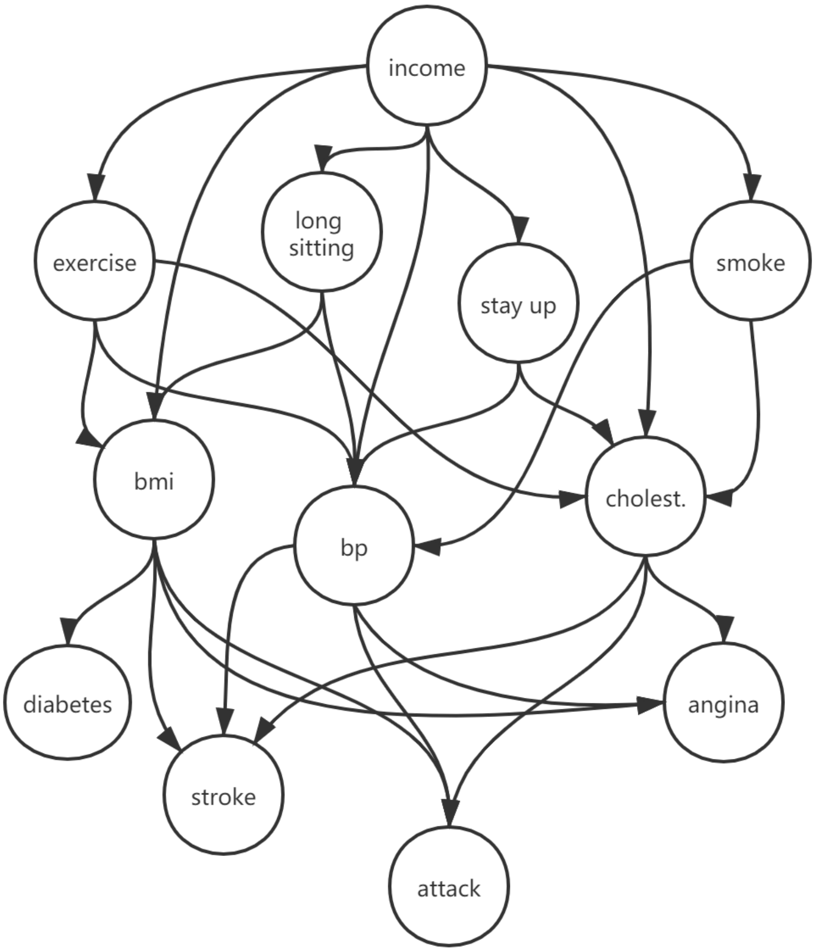
1 Coding Part

In this assignment you will implement code for computing exact inferences in Bayesian networks of discrete random variables using variable elimination. Before you start coding, be sure to read the PandaTutorial.pdf. Then you can implement the code **BayesianNetworks.py**. Two functions are already written, **readFactorTable** and **readFactorTablefromData**, which build conditional probability tables, represented as factors. See the source file **BayesNetworkTestScript.py** for a demonstration of how these work. Your job is to implement the following functions:

- **joinFactors(Factor1,Factor2)**
  Should return a factor table that is the join of factor 1 and 2. You can assume that the join of two factors is a valid operation. Hint: You can look up pd.merge for merging two dataframes.
- **marginalizeFactor(factorTable, hiddenVar)**
  This function should return a factor table that marginalizes margVar out of it. Assume that hiddenVar is on the left side of the conditional. Hint: you can look up pd.groupby.
- **marginalizeNetworkVariables(bayesNet, hiddenVar)**
  This function takes a Bayesian network, **bayesNet**, and marginalizes out a list of variables **hiddenVar**.
- **evidenceUpdateNet(bayesnet, evidenceVars, evidenceVals)**
  This function takes a Bayesian network, **bayesNet**, and sets the list of variables, **evidenceVars**, to the corresponding list of values, **evidenceVals**. You do not need to normalize the factors to be proper probabilities (no need to sum to 1).
- **inference(bayesnet, hiddenVar, evidenceVars, evidenceVals)**
  This function takes in a Bayesian network and returns a single joint probability table resulting from the given set of evidence variables and marginalizing a set of hidden variables. You should normalize the table to give valid probabilities. The final table should be a proper probability table (entries sum to 1). The hidden variables shown in **hiddenVar** should not be in the returned table.

2 Written Part

In this part you will be analyzing risk factors for certain health problems (heart disease, stroke, heart attack, diabetes). The data is from the 2015 Behavioral Risk Factor Surveillance System (BRFSS) survey, which is run by the Centers for Disease Control (CDC). The distilled data is in the spreadsheet **RiskFactorData.csv**. The variables and their meanings are as follows:



- **income** - Annual personal income level.

$1(<\$10,000)$	$2(\$10,000-\$15,000)$	$3(\$15,000-\$20,000)$
$4(\$20,000-\$25,000)$	$5(\$25,000-\$35,000)$	$6(\$35,000-\$50,000)$
$7(\$50,000-\$75,000)$	$8(>\$75,000)$	

- **exercise** - Exercised in past 30 days.
  1(yes) , 2(no)
- **smoke** - Smoked 100 or more cigarettes in lifetime.
  1(yes) , 2(no)
- **long sitting** - Sitting for more than 6 hours every day.
  1(yes) , 2(no)
- **stay up** - Usually stay up late until 12pm.
  1(yes) , 2(no)
- **bmi** - Body mass index (category).
  1 (underweight), 2 (normal), 3 (overweight), 4 (obese)

- **bp** - Has high blood pressure.
  1 (yes), 2 (only when pregnant), 3 (no), 4 (pre-hypertensive)

- **cholesterol** -Has high cholesterol.
  1(yes) , 2(no)

- **angina** - Had heart disease (angina).
  1(yes) , 2(no)

- **stroke** - Had a stroke.
  1(yes) , 2(no)

- **attack** - Had a heart attack.
  1(yes) , 2(no)

- **diabetes** - Had diabetes.
  1 (yes), 2 (only during pregnancy), 3 (no), 4 (pre-diabetic)

Do the following, and write up your results in your homework submission
le(to back up your claim, please provide screen shot of your program results).

1. Create the following Bayesian network to analyze the survey results. You will want to use the provided function **createCPTfromData**.
   What is the size (in terms of the number of probabilities needed) of this network? Alternatively, what is the total number of probabilities needed to store the full joint distribution?

2. For each of the four health outcomes (diabetes, stroke, heart attack, angina), answer the following by querying your network (using your infer function):

   (a) What is the probability of the outcome if I have bad habits (smoke , don't exercise,long sitting and stay up)? How about if I have good habits?

   (b) What is the probability of the outcome if I have poor health (high blood pressure,high cholesterol, and overweight)? What if I have good health (low blood pressure, low cholesterol, and normal weight)?

   Organize these results in an easy-to-read format (e.g., tables) in your write-up.

3. Evaluate the effect a person's income has on their probability of having one of the four health outcomes (diabetes, stroke, heart attack, angina). For each of these four outcomes, plot their probability given income status (your horizontal axis should be $i = 1, 2, \ldots, 8$, and your vertical axis should be $P(y = 1|income = i)$, where y is the outcome). What can you conclude?

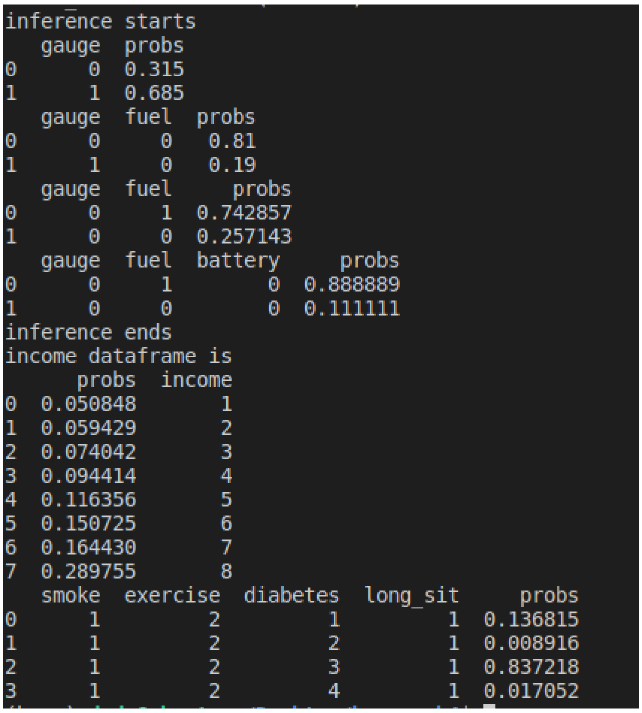
4. Notice there are no links in the graph between the habits and the outcomes.
   What assumption is this making about the effects of smoking and exercise on health problems? Let's test the validity of these assumptions. Create a second Bayesian network as above, but add edges from smoking to each of the four outcomes and edges from exercise to each of the four outcomes. Now redo the queries in Question 2. What was the effect, and do you think the assumptions of the first graph were valid or not?

5. Also notice there are no edges between the four outcomes. What assumption is this making about the interactions between health problems? Make a third network, starting from the network in Question 4, but adding an edge from diabetes to stroke. For both networks, evaluate the following probabilities:

   $$P(stroke = 1|diabetes = 1) \quad and \quad P(stroke = 1|diabetes = 3)$$

   Again, what was the effect, and was the assumption about the interaction between diabetes and stroke valid?

6. Finally, make sure that your code runs correctly on all of the examples in **BayesNetworkTestScript.py**. You need to update **BayesianNetworks.py** to support your earlier written part. Your code will be graded for correctness on these also. To check correctness, a screen-shot of the output is shown below.



```
inference starts
   gauge  probs
0      0  0.315
1      1  0.685
   gauge  fuel  probs
0      0     0   0.81
1      1     0   0.19
   gauge  fuel     probs
0      0     1  0.742857
1      0     0  0.257143
   gauge  fuel  battery     probs
0      0     1        0  0.888889
1      0     0        0  0.111111
inference ends
income dataframe is
      probs  income
0  0.050848       1
1  0.059429       2
2  0.074042       3
3  0.094414       4
4  0.116356       5
5  0.150725       6
6  0.164430       7
7  0.289755       8
   smoke  exercise  diabetes  long_sit     probs
0      1         2         1         1  0.136815
1      1         2         2         1  0.008916
2      1         2         3         1  0.837218
3      1         2         4         1  0.017052
```

3 Submission instructions

1. Zip **BayesianNetworks.py** , **BayesNetworkTestScript.py** and HW4_name_id.pdf to a folder called hw4_name_id.zip

2. Upload the zip file to https://jbox.sjtu.edu.cn/l/eHE74r